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Experimental Researches into the Function of the Cerebellum. J. S. RISIEN RUSSELL. Phil. Trans. Roy. Soc., 1894, II, pp. 819-61, 11 Figs. in text.

Degenerations Consequent on Experimental Lesions of the Cerebellum. J. S. RISIEN RUSSELL and A. W. CAMPBELL. Brit. Med. J., Lond., 1894, II, 640-42; also, Proc. Roy. Soc., LVI, 303-5. 1895.

A Clinical Study of a Cyst of the Cerebellum; Weakness of Spinal Muscles; Death from Failure of Respiration. J. S. RISIEN RUSSELL with J. HUGHLINGS JACKSON. Brit. Med. Journal, Lond., 1894, I, pp. 393-5.

The Value of Experimental Evidence in the Diagnosis of Diseases of the Cerebellum. J. S. RISIEN RUSSELL. Brit. Med. J., Lond., 1895, I, pp. 1079-82.

Defective Development of the Central Nervous System in a Cat. J. S. RISIEN RUSSELL. Brain, 1895, Lond., pp. 37-53, 10 Figs.

The cerebellum has been studied since Saucerotte with ever confusing and indefinite results. And it is only within the last two years that sufficient light as to its varied functions has been gained to place lesions of the cerebellum within the field of practical operative surgery. Much of the final work to this end has been accomplished by Dr. Russell, and is outlined in the above papers.

We are first treated to a brief review of the literature, including the recent work of Luciani, and from this is clearly seen the necessity of focussing experiment on the following seven points: 1, "Whether each lateral half of the cerebellum is capable of acting independently, or whether it is necessary for the connections between the two halves to be intact, in order that the functions of the organ should be properly performed." 2. "If impulses pass from one side of the organ to the other before they are transmitted to the cerebrum or spinal cord." 3. "What is the nature of the impairment of movement which results when portions of the organ are removed?" 4. "What relationship exists between one-half of the cerebellum and the cerebral hemisphere of the opposite side, and what is its probable nature?" 5. "Whether one lateral half of the cerebellum is related mainly to one side of the spinal cord, to the opposite side, or to both, and what the nature of the relationship is." 6. "What symptoms resulting from experimental lesions of the cerebellum are mostly to be relied on for localization?" 7. "Whether any, and if so, which, of the symptoms are dependent on interference with the labyrinth or eighth nerve when experimental lesions of the cerebellum are produced." The research is thus seven-fold, including all the difficult and disputed points of cerebellar physiology, and for each point a special line of experiments was planned. Most of the experiments were made upon dogs, results of these, however, being compared with those obtained from monkeys, and the case of a cat with defect in development of cerebellum sufficing to show very similar relations in this species.

Median section of the cerebellum, the line of experiment employed to prove whether the cerebellum acted as a unit or as a bilateral organ, caused remarkably little disturbance. This is taken to indicate, in contradiction to Luciani's reiterated dictum, "that the cerebellum is a unit; that one-half of the cerebellum does not, in any great measure, depend on the coöperation of the other half for the proper performance of its functions. The bulk of the impulses pass from one-half of the organ to the cerebrum, or to the

spinal cord, without passing to the other half." Thus this refractory part falls into line with all the other parts of the nervous axis as a bilateral organ, and a foothold is gained for the experiments to follow.

The most important results touching the relations of the cerebellum to the cerebrum on the one side and to the spinal cord on the other, are thus naturally given by ablation of one lateral half of the organ. A striking result of this operation is shown in the increased excitability of the opposite cerebral hemisphere. Tested with the faradic current, with cerebellum intact, both hemispheres are equally excitable. After ablation of one-half of the cerebellum the opposite hemisphere becomes much more excitable, and continues so for at least three months after the operation. This is also clearly demonstrated by the administration of absinthe, the contractions occurring during the epileptic seizures being enormously greater on the side of the ablation, while it was also clear that the convulsions on the other side were diminished. Furthermore, the character of the convulsions on the two sides tends to become different, in intact animals the characteristic tonic contractions tending strongly to become clonic upon the operated side. The tracings taken from several experiments and reproduced in the first paper noted show these differences in a striking manner.

Impairment of movement occurs after unilateral ablation. This Luciani explains as due to his three factors, *astasia*, *asthenia* and *atonia*. Russell also distinguishes three factors, which he names *incoördination*, *rigidity* and *motor paresis*. The two former conditions would seem to be due chiefly to the increased excitability of the opposite cerebral hemispheres; the paresis, as the author states, is "probably directly due to the withdrawal of the cerebellar influence from the muscles." The chief result of this line of experiments is that "the one-half of the cerebellum controls the cells of the cortex of the opposite cerebral hemisphere, and those of the anterior horns of the spinal cord on the same side chiefly, and on the opposite side to a slight extent." Thus, while the cerebrum has chiefly a crossed relation to the body, the relation of the cerebellum is mainly direct.

The symptoms characteristic of unilateral ablation of the cerebellum are summarized as follows: 1. Rotation and reeling to the opposite side. This is a prime symptom, and is the exact opposite of the results of most other observers, who state that the reeling is toward the side of the lesion. Further, when describing the phenomenon in an affected person, Dr. Russell clearly indicates that "the turning is toward what I should call the side of the lesion." For right unilateral ablation the rotation is that of a "cork-screw going into a cork;" for left ablation, that of a "cork-screw coming out of a cork," that is, to the right for right lesion and to the left for left lesion. Attention has been called to this apparent discrepancy, and Dr. Russell has rejoined that he intends clearing up the matter in a special paper.

Among the other symptoms, the face on the affected side is turned upward and the spinal column is convex on the side of lesion; and there is *incoördination*, *rigidity*, especially of the fore limb, exaggeration of tendon reflexes, motor paresis, *anæsthesia* and *analgesia*, the three latter also affecting the posterior extremity of the opposite side. The opposite eyeball deviates downwards and outwards, while that of the same side, if abnormal, turns upwards and to the affected side. Nystagmus also occurs, in which the jerks are toward the side of lesion.

The general result of the whole research is that instead of considering the cerebellum as a distinct organ and trying to prove

a distinct function for it, we should treat it as a part of the great central axis, which coöperates with many other parts in the performance of many different functions, the chief difference between one part of this great system and another being the degree in which different functions are represented in any given part: *e. g.*, with regard to motor power, the anterior extremity is maximally represented in the cerebrum and minimally in the cerebellum, whereas the trunk muscles are minimally represented in the cerebrum and maximally in the cerebellum. The disturbances of eye movements, which Luciani considered "irritative," Russell would make paralytic. Experiments in various ways on the auditory nerve and labyrinth prove that disturbances in this region are different from those arising from cerebellar lesion.

The whole clinical bearing of his investigations, together with references to a number of clinical cases, is discussed in the papers referred to in the *British Medical Journal*.

Degenerations following removal of various parts of the cerebellum, especially those occurring after unilateral ablation, are of especial interest as confirming or failing to confirm the results of Marchi, Ferrier and Turner. "Removal of one lateral lobe of the cerebellum results in degeneration of all the peduncles on the side of the lesion, and in the superior peduncle of the opposite side. The degenerated fibres in the superior peduncle on the side of the lesion decussate in the posterior quadrigeminal region, and pass to the opposite red nucleus and optic thalamus. None could be traced beyond this point." The degenerated fibres in the opposite superior peduncle came from the region of the cut, and occurred in both superior peduncles after median section. This is taken to controvert Marchi's statement that none of the peduncles contain commissural fibres. The degenerated fibres of the middle peduncle pass to the gray matter of the opposite side of the pons. Marchi's result that fibres from this peduncle pass in the fillet and posterior longitudinal bundle to the corpora quadrigemina, in the pyramids to the corpora striata, or to the roots of the cranial nerves, is not confirmed. Fibres degenerating in the inferior peduncle occupy the lateral region of the medulla, thinning out rapidly as they pass down. A few scattering fibres can be traced in the antero-lateral region of the cervical cord, where all signs of degeneration cease. Degenerated fibres pass in this peduncle to both inferior olives. Russell confirms Marchi, contrary to the results of Ferrier and Turner, in demonstrating degenerated fibres in all the peduncles after excision of the middle lobe. Ferrier and Turner, on the other hand, are confirmed against Marchi in not finding any antero-lateral tract degenerated throughout the length of the cord, where only the cerebellum is injured.

In this connection it is of interest to note that Campbell's findings in several human cases (*Brit. Med. Jour.*, part of Russell's paper) gives the startling result of degeneration downward in the direct cerebellar tract in unilateral lesion of the cerebellum. In the cat, too, with defective development of the right lobe of the cerebellum, deficiency also occurs in the corresponding direct cerebellar tract. Attention was called to this animal by its resemblance to Dr. Russell's dogs with unilateral ablation of the cerebellum. The post mortem examination fully confirmed Russell's diagnosis, the right lobe of the cerebellum being scarcely one-third the size of the left. This case furnishes, among others, one other point of especial interest. Whereas the right cerebral hemisphere is but slightly smaller than the left, the right crus is very small and completely disappears in the upper levels of the pons, so that no trace

of a right pyramid is observable in the medulla. At the usual level the left pyramid divides, as in some of Mellus's cases, the greater part passing to the right side, about a fifth remaining on the left side. The striking point, however, is that the cord below the decussation very soon comes to present perfectly normal pyramidal tracts. It is difficult to explain how this can happen on any other assumption than that some, and it would seem the larger part, of the pyramidal fibres really arise in the cord, and not in the cortex, as is usually taught.

We are certainly indebted to Dr. Russell for a vigorous stirring of these already troubled waters, and there appears to be good reason to hope that they will clear into a much better anatomy and physiology of this difficult region than we have had heretofore.

C. F. H.

An Experimental Investigation of Eye Movements. J. S. RISIEN RUSSELL. *Journal of Physiology*, XVII, Nos. 2 and 3, pp. 1 to 27, 3 Figs. in text.

A serious difficulty in the localization of eye movements in the cerebral cortex has been the fact that only lateral movements have been obtained from cortical stimulation. Hughlings Jackson recently made the suggestion that the absence of other movements might be accounted for by the *degree* of representation of the various movements in the same general centre, the lateral movements of the eyes being predominantly represented over the area for control of the eyes. If this supposition be correct, by excluding these movements, cutting the lateral recti, it ought to be possible to obtain other movements on stimulating the motor eye centres. An experimental test of this suggestion in the hands of Dr. Russell proved Jackson's view to be correct, and this result cannot fail to exert a widespread influence upon general theories of cerebral localization. Beyond this point Dr. Russell discusses the relative control of the eyes by the cerebellum and cerebrum.

By cutting the external rectus of one side and internal rectus of the other, and stimulating the cortex of the side with the intact recti, the possibility of lateral movements was excluded and practically all the other movements of the eyes were obtained, viz., direct downward and upward rotations, rotations downward and to the opposite side and upward and to the opposite side, and occasionally also convergence, were obtained, each corresponding to a more or less clearly defined cortical area.

Ocular deviations artificially produced in dogs by ablation of the whole or part of the cortical area for eye movements on one side are recovered from in time, but reappear in narcosis, to be lost again in the total paralysis of the eye muscles normally occurring in the deeper states. Explanations founded on hypertrophy of residual cells, cerebellar compensation and compensation by the other hemisphere are suggested, but none is supported to the exclusion of the others. Careful control experiments on normal dogs were conducted to exclude false results.

Extirpation of one lateral half or part of one lateral half of the cerebellum produces downward and variable outward rotation on the opposite side. Total excision produces a downward and slightly outward rotation of both eyes. All experimentally induced rotations ultimately disappear, but may be caused to reappear in narcosis. Nystagmus is generally also present with slow jerking movements immediately after lesions, or, in cases of total extirpation, accompanying, and in the same direction as, voluntary move-